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CONFIDENTIALAndy *[Signature]*

25X1

September 29, 1959

Dear Sir:

This letter report summarizes the research performed under Task Order No. FF during July and August, 1959.

An investigation of the operating characteristics of the transmitter has been made. The purpose of this investigation was to determine the transmitter susceptibility to uncontrollable variables introduced into the system . A slight dependence on input pulse width was discovered. This has thus far been reduced but not completely eliminated, and will be investigated further. Also, as a result of the investigation, some jitter was observed; however, it appears to be normal for this type of circuitry.

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Tests have been conducted to determine the system performance under normal  conditions. The results obtained thus far indicate that accuracy is not affected by  speeds used, but there is a tendency for . This is attributed to insufficient resolving time. A study is being made to determine how much the resolving time of the system can be increased without grossly altering the circuitry or decreasing the accuracy.

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Also, range tests have been conducted and the results obtained were quite favorable. Accurate transmission was possible for distances up to 100 feet in the presence of considerable interference. Ranges in excess of 250 feet were possible when very little interference was present.

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*Summary*~~SECRET~~

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September 29, 1959

A method of storing the transmitted information on tape so that it can be processed at a later time has been developed. Final modifications for optimizing this method are being made.

We currently expect to have the entire system in finalized form during the early part of October. Thus, we recommend that you start planning for a demonstration of the over-all system at your facility almost any time after the middle of October.

The original appropriation on this Task Order was \$21,179. As of September 1, 1959, the unexpended balance was approximately \$5,800.

Sincerely,

*A*  


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 Andy - [signature]



July 22, 1959

Dear Sir:

This letter report summarizes the research performed under Task Order No. FF during June, 1959.

The investigation of the operating characteristics of the whole monitoring system is continuing. The investigation has resulted in further modification of the transducer, pulse converter, and decoder. In its present state, reliable operation of the system is possible for periods of several days under ideal laboratory conditions. However, better resolution is desirable for field operating conditions, if it can be easily obtained. The major deviations are in the transducer-transmitter portion of the system. These deviations stem mainly from characteristic properties [redacted] Over-all resolution is 25X1  
 limited by the nonlinear spacing [redacted] Pulses produced by the 25X1  
 transducer differ slightly in width because of variations in the dynamic characteristics of the [redacted] 25X1

These variables cannot be controlled. In its present state, the transmitter is somewhat sensitive to pulse-width variation. This component has been designed to be insensitive to this type of variation, but further improvement will be required in order to obtain the resolution required for field operating conditions.

Plans for next month are to modify the transmitter and permanently install the modifications made in the other parts of the system.

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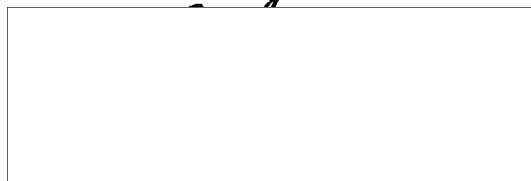
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July 22, 1959

The original appropriation on this Task Order was \$21,179.

As of July 1, 1959, the unexpended balance was approximately \$11,100.

Sincerely,



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June 11, 1959

*Rec'd ED  
6/15/59*

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*Wann JWD*

Dear Sir:

This letter report summarizes the research performed under Task Order No. FF during May, 1959.

An investigation of the operating characteristics of the transmitter and pulse converter has been started. The results obtained from the initial tests conducted on the pulse converter indicate that satisfactory performance should be obtained from this device in its present state. The performance of the transmitter has been erratic, however. This may, in part, be due to our lack of familiarity with its operation. For this reason, it appears advisable to consult with a representative of the organization which developed this unit. We would appreciate your arranging for such a meeting in the near future.

The improvement effort on the transducer is nearing completion. The remaining work will involve an investigation of its aging properties and durability.

Plans for next month include continuing with the evaluation program in progress as described above and formulating procedures for conducting the contemplated range tests.

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June 11, 1959

The original appropriation on this Task Order was \$21,179.  
As of June 1, 1959, the unexpended balance was approximately \$13,800.

Sincerely,



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May 21, 1959

Plans for next month include initiating long-term-reliability experiments with the decoder and continuing with the transducer work. Also, to initiate stability evaluation, the transmitter and pulse converter will be placed in operation.

The original appropriation on this Task Order was \$21,179. As of May 1, 1959, the unexpended balance was approximately \$16,300. *mlm*

Sincerely, */*



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August 1, 1955

Dear Sir:

Enclosed is the Summary Report dated June 30, 1955, describing the activity on Research Order No. 15 from March 28 through June 30, 1955, the current expiration date.

The research on the transducer and the cursory investigation of a decoding system have demonstrated the feasibility of these two major components of the three-component system. It is believed that three problems that are major but amenable to solution exist relative to the overall system:

(1) The decoding-system design must be carried through the stage of actual construction.

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(3) The three major system components must be integrated so that they are mutually compatible and comprise a system that represents the maximum possible ease and stability of operation.

A proposal has been prepared covering research on Item (1) above. This is being transmitted under separate cover.

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August 1, 1955

The original appropriation on this Research Order was \$12,000.00.  
As of June 30, 1955, the current termination date, the unexpended balance  
was approximately \$600.00.

We would appreciate any comments that you or your associates  
might care to make with regard to the research.

Sincerely,

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ABW:dp

Enclosure

In Triplicate

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**SUMMARY REPORT**

**RESEARCH ORDER NO. 15**

**June 30, 1955**

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amplitudes and the polarity to identify the 42 keys. With 21 amplitudes to be recognized, a minimum difference in amplitude between two adjacent keys of about 4 per cent exists at each end of the transducer.

Since the time duration of the pulses is a variable and since even 2 milliseconds is too short a period to use for recognizing and classifying a pulse, it appears that there is a basic problem in stretching the pulses to a greater length. If the pulses can be stretched without changing their amplitudes, decoding becomes possible.

On the basis of a pulse repetition rate of 8.3 pulses per second, it appears that a maximum time of 120 milliseconds is available for the decoding of a single letter. To provide a reasonable margin, it has been assumed that complete decoding of each letter must take place in a maximum of 100 milliseconds. It is possible to stretch the pulses the required amount in a very simple way. This is done with the aid of a circuit such as that shown in Figure 1.

If a positive voltage is suddenly applied to the input, capacitor  $C_1$  will charge through the rectifier with a time constant of  $R_f \times C_1$ , where  $R_f$  is the forward resistance of the rectifier. Once charged,  $C_1$  will discharge through the rectifier and  $R_1$ ; however, the time constant of the discharge circuit is  $R_r \times C_1$ , where  $R_r$  is the reverse resistance of the rectifier. If the rectifier is a silicon junction type, the reverse resistance may commonly be 10,000 times the forward resistance. Thus, if, for example,  $C_1$  would charge within 1 per cent of the applied voltage in 1 millisecond, 10 seconds would be required for the charge to decay 1 per cent. It is evident, therefore, that where times of 1 to 2 milliseconds are available to charge  $C_1$ , holding the

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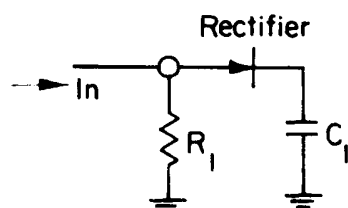


FIGURE 1. SCHEMATIC DIAGRAM FOR BASIC PULSE-STRETCHING CIRCUIT

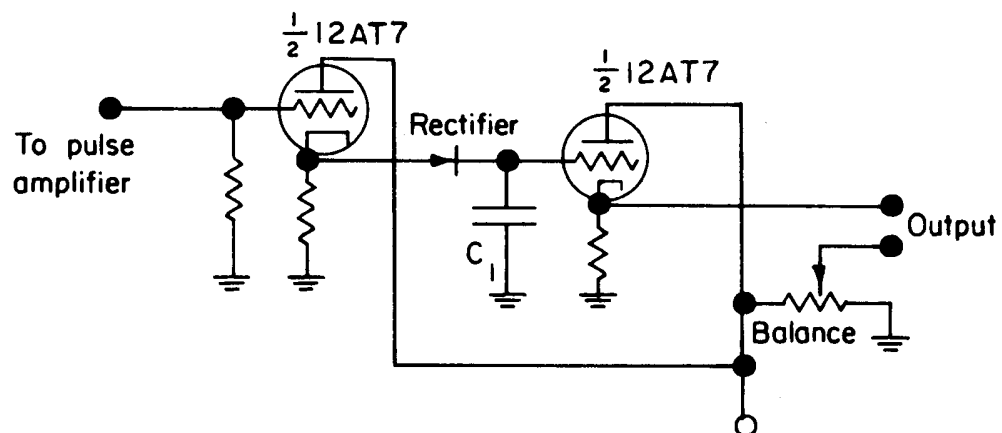


FIGURE 2. SCHEMATIC DIAGRAM OF SATISFACTORY PULSE AMPLIFIER

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charge for 100 milliseconds is relatively easily accomplished.

A satisfactory pulse-stretching circuit was constructed utilizing this principle. This device is diagrammed in Figure 2.

A cathode follower is used to provide a low impedance source, so the charging time of  $C_1$  is low. A second cathode follower is used to insure that  $C_1$  is connected to a high impedance system and, therefore, will discharge only through the rectifier. The output circuit is provided with a balance control which can be used to adjust for zero voltage from the system when at rest.

A decoding system was constructed, as described in some detail in the Summary Report dated March 28, 1955, using available parts; this was not meant to represent the ultimate in a decoding apparatus. However, it did serve to illustrate the feasibility of an automatic decoding system.

The basic principle of the system previously reported was to provide a separate amplitude-sensing element for each of the 21 amplitudes to be classified. An interlocking circuit was then arranged so that only the desired amplitude produced an output, even though in this particular case all sensing elements of lesser amplitude than the one to be selected would also operate. This system might be described as a parallel or simultaneous system. It has the advantage that the time required for a classification is only the time required to operate a single sensing device. The time is also the same regardless of the classification. A serious disadvantage is the necessity for providing a stable reference system for each classification. Thus, a system of this sort would be subject to drift and instability.

Consideration of the possible methods of decoding led to the decision that a single element should be utilized as a reference. As a basic

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principle, it appeared that a comparison system utilizing a series of voltages derived from a precision voltage divider and a circuit to sense equality between the pulses being decoded and the divider voltage would provide the maximum stability. The operation of such a system can be described simply with the aid of Figure 3.

In Figure 3, a voltage divider is arranged with an excitation E. An amplifier is connected to a relay and operated in a manner such that, when the voltage between a and b is zero, the relay will operate. The operation of this relay will shut off the power to the driving motor which moves scanning arm b. When this occurs, the position of scanning arm b will correspond to the position of the original action on the transducer.

A variation of this system is one where the divider is made up of a series of discrete steps rather than a continuous element. The scanning arm is then replaced by a series of relay contacts which operate in sequence. The number of discrete steps can be made to be the same as the number of steps or classifications required from the transducer.

The principal advantage of this arrangement over the previously described system is the great improvement in stability. In contrast with the previously described device where 21 separate amplitude circuits were required, only one is required in this case, assuming, of course, that a stable voltage divider has been achieved. This is a relatively easy requirement to meet. A further advantage of this system is the reduction in over-all complexity.

Since the engineering features of the single-reference system were so advantageous, this method of classifying was considered to repre-

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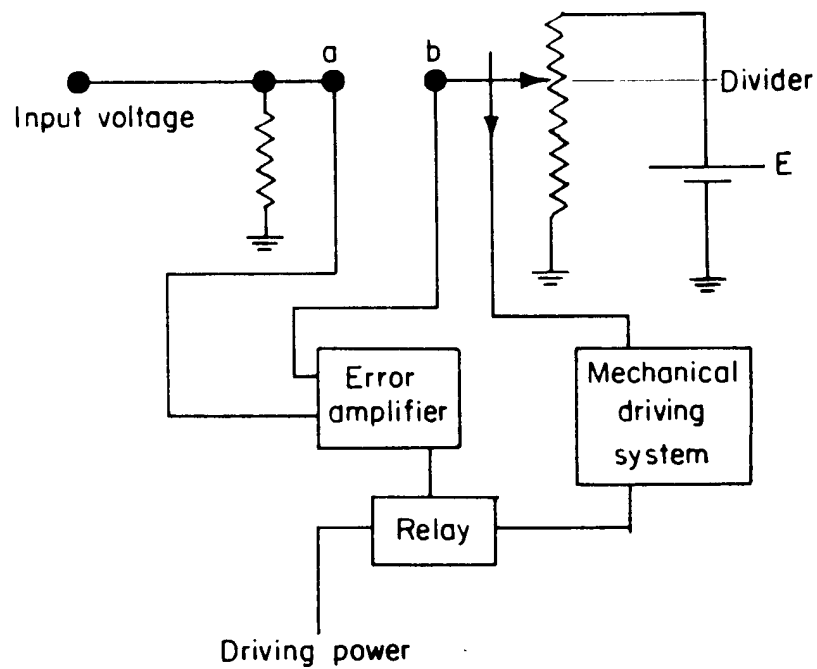


FIGURE 3. SCHEMATIC DIAGRAM OF A SIMPLIFIED CLASSIFIER

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sent the soundest approach. Consequently, a classifier was designed using this basic principle.

This classifier is an all-relay device, except for the circuits which sense zero difference between the reference level and the incoming-signal level, and could be described as a two-stage classifier. One of the characteristics of such a scanning or comparison type of device is that a sequence of events must take place to permit a classification to be made. The maximum number of events that may be required is at least equal to the number of classifications that are required. Where only about 100 milliseconds are available for making a classification, the sequencing may require too much time. Therefore, the device designed splits the operation into two parts. The 21 total classifications are split into three groups of 7 each. It is then necessary to identify the group and the hit in the group to make a selection of a particular classification. Rather than 21 operations, this set up requires a maximum of 10 operations and thus effects a large saving in required time. The schematic diagram of this classifier is shown in Figure 4.

In order to explain the operation of this classifier, a step-by-step description of the selection of a given classification will be made.

There are two relay counting chains in this classifier. One, a chain of 3, is identified by the letters a, b, and c. The other, a chain of 7, is identified by the numbers 1 through 7. In Figure 4, the pulse amplifier is shown in block form, and all of the relays are in the at-rest position with power applied to the system.

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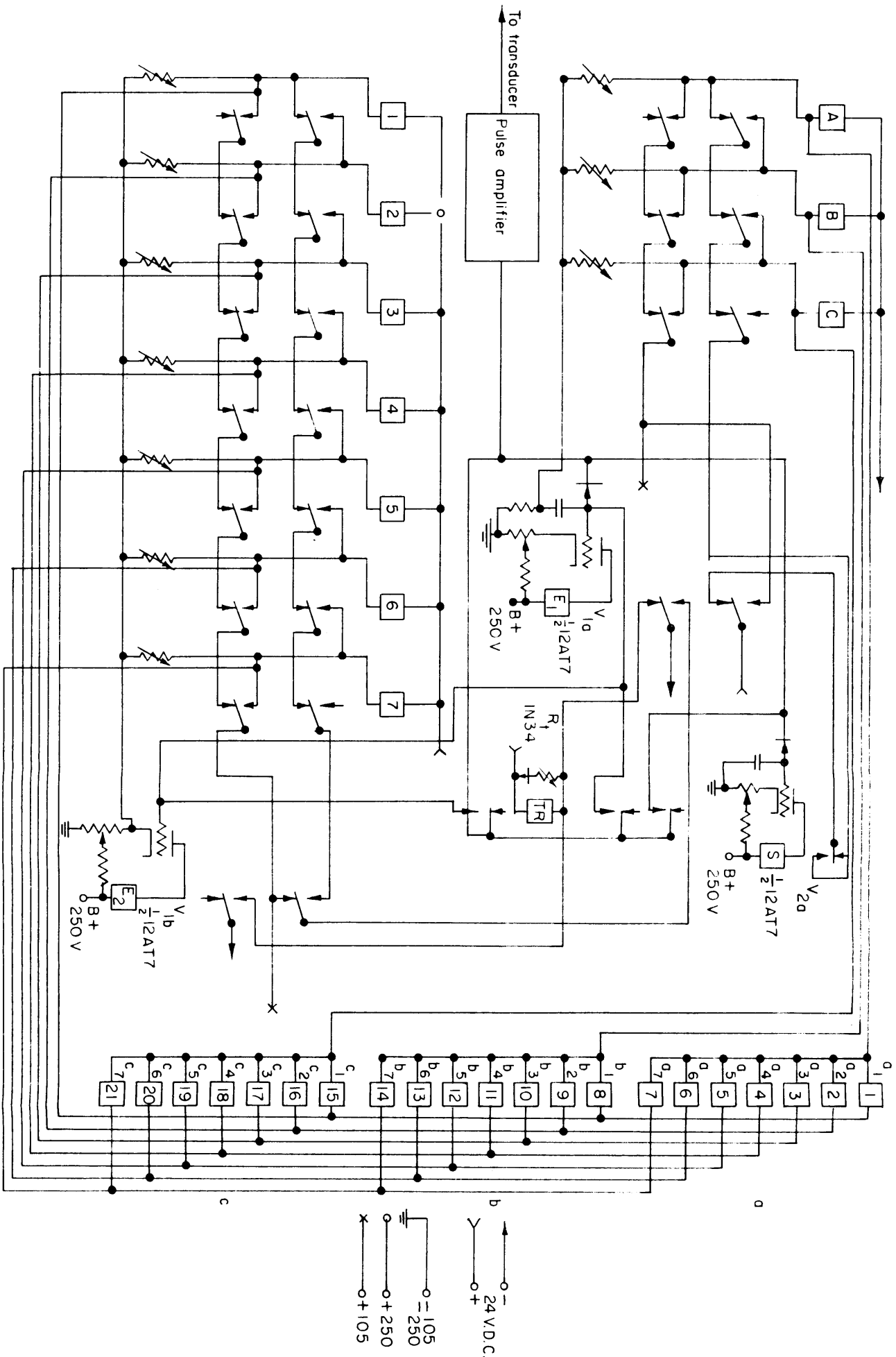
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FIGURE 4. SCHEMATIC DIAGRAM OF A TWO-STAGE CLASSIFIER

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Assume that a signal is received by the pulse amplifier that corresponds to a classification of number 19 or c5. The amplified pulse is applied to the grid circuits of  $V_{1a}$ ,  $V_{1b}$ , and  $V_{2a}$  through the rectifiers associated with these circuits. As previously explained, the capacitors in these grid circuits will store the energy, with no appreciable loss of voltage, over the interval required for a classification.  $V_{2a}$ , which was in a conducting condition, will be cut off, dropping relay S.  $V_{1a}$  and  $V_{1b}$  were already in a nonconducting condition, so no action will take place at those points since they will simply become further cut off. The dropout of relay S applies battery to relay A through a relay S back contact through relay  $E_1$  down and through A, B, and C down. Relay A then picks up and applies voltage through a divider to the grid circuit of  $V_{1a}$ . This voltage is in a direction that favors tube conduction. At the same time, the pickup of A closes the pickup circuit of B and opens A. A drops out and B picks up. B applies a still greater voltage to the grid circuit of  $V_{1a}$ . In the same way, C picks up.

However, in the example chosen, when C picks up, the voltage applied to  $V_{1a}$  that is the difference between the pulse voltage and the voltage through the divider from relay C will be such that  $V_{1a}$  will conduct, picking up relay  $E_1$ . When  $E_1$  picks up, voltage is applied through a front contact of  $E_1$  and a front contact of C that keeps C picked up. Thus, the action to this point has indicated that the voltage being classified is one of seven voltages in the range from B to C. Note also that, when C is stuck up, the left-hand sides of relays 15 through 21 or  $C_1$  through  $C_7$  are connected to battery.  $V_{1b}$  which is connected in parallel with the  $V_{1a}$  grid circuit also

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conducts at this time, picking up relay  $E_2$ . Battery is then applied to relay 1 through  $E_1$  and  $E_2$  up, and through 1 through 7 down. The 7 chain then operates, applying progressively higher voltages to the cathode circuit of  $V_{1b}$  in a direction which tends to cut off  $V_{1b}$  and drop  $E_2$ . For the example given,  $E_2$  will drop when relay 5 picks up. Relay 5 will then be stuck through its own front contact, a front contact of  $E_1$  which is up, and a back contact of  $E_2$  which is down. When  $E_2$  drops, sticking 5, voltage is applied to the right-hand sides of relays 5, 12, and 19. Of these three relays, 19 is the only one which already has its left side connected to battery because of C being stuck up. Therefore, relay 19 will operate.

In order to terminate the action after a reasonable period, in this case in 100 milliseconds, TR has been provided. When  $E_1$  is up and  $E_2$  down, the operate circuit of  $E_2$  is opened. A time delay is provided across the coil of TR. After the desired interval, TR drops and shunts the rectifiers in the memory circuits. This drops  $E_1$  and allows S to pick up. Then S opens the stick circuits to the chains, thus resetting the system. Since the input pulse was of short duration, the system will wait until the next pulse before further action takes place.

Output relays 1 through 21 are visualized as solenoids which can be arranged over the keyboard of a typewriter so that the action will automatically produce a printed record of the input information. Solenoids of the required size can probably be obtained commercially that provide more than adequate force to actuate the keys of an electric typewriter.

The relays required for the classifier described would in all cases except for TR be Stevens Arnold Millisec units. Care has been taken

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in designing the circuit to keep the contact requirements low so that D.P.D.T. relays can be utilized. These relays are available at about \$7.00 each in small quantities. With relays of this sort, it is estimated that the maximum time required for a classification will be about 15 milliseconds. Thus, about 85 milliseconds of the total 100-millisecond interval will be available . A possible source of solenoids for key actuation is those units which are used in some photoflash camera attachments to supply the shutter operating force.

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#### CONCLUSIONS AND RECOMMENDATIONS

It is believed that the successful development of a transducer and the effective concealment of this device, as has been demonstrated, effectively answers the most pressing question as to the possibilities of the system. The supplementary work which has been accomplished has shown the feasibility of an automatic printing decoder. However, three major problems exist and must be solved in order to achieve a workable over-all system:

- (1) The decoding-system design must be carried to the point of actual construction and improvement of the system described.

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- (3) After, and to some extent during, the development of the major system components, attention must be given to the integration of these components, in order to insure a compatible set of devices, and maximum possible ease and stability of system operation.

It is believed that these problems can be solved and that the resulting system will be relatively simple and reliable. It appears that the system which can be visualized with relative assurance at the present time has characteristics that are superior to those hoped for at the start of the program.

It is recommended that research on the decoding system be continued to the stage of proving the principles already laid down by building a practical decoding device. A detailed proposal covering this research and coordination of the characteristics of the transducer and decoder to insure optimum performance has been prepared and is being transmitted under separate cover.

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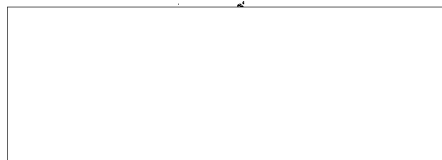
April 28, 1955

Dear Sir:

Enclosed are three copies of the Summary Report on Research Order No. 15, covering the period from June 28, 1954, to March 28, 1955.

We would appreciate any comments that you or your associates may care to make with regard to the research.

Sincerely,



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Enclosure

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**SUMMARY REPORT**  
**ON**  
**RESEARCH ORDER NO. 15**

**March 28, 1955**

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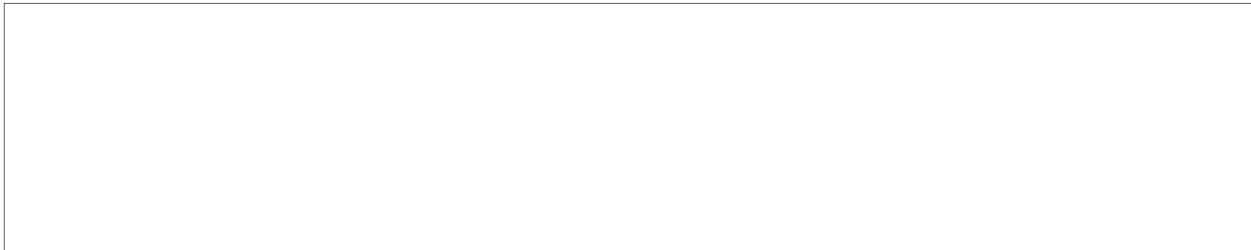
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In a life test, this transducer operated without failure for one million repetitions of the coming-to-rest action at a single location, thus indicating satisfactory life.



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A cursory investigation has been made of the decoding problem. A decoder with a capacity  was prepared as part of an entire monitoring system that used wire rather than radio transmission, and was found to be feasible.

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### GENERAL DESCRIPTION OF RESEARCH

#### Transducer Forms

During the course of this research, transducers with different physical forms were constructed and tested.

The original proposal described a transducer with conductive rubber as the resistive element. The conductive element was visualized as thin metal foil bonded to a piece of ordinary rubber. These two elements were to be held apart by means of a slight positive air pressure inside the transducer.

Devices of this sort were constructed. Preliminary study indicated that the resistive material must be stable, easily applied, and flexible

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mechanically. Investigation of conductive rubber as the resistive element revealed that this material did not satisfy the requirement of stability. The resistive-element problem was solved by preparing a resistive paint composed of equal parts, by volume, of Shawinigan acetylene (carbon) black\* and Pliobond 20 adhesive\*\*. This combination was thoroughly mixed to a creamy consistency. Sufficient methyl ethyl ketone solvent was then added to reduce the viscosity of the mixture, so that it could be easily brushed onto the desired surface. The resistance desired is obtained by using multiple coats of this mixture. This material adheres well to rubber or plastic surfaces and has been used throughout this development for preparation of the resistive strip.

The conductive strip used in the various forms of the transducer has been constructed in two ways. A metal foil strip was used originally. Difficulty was experienced with this arrangement because uneven shrinkage of the strip and of the material carrying the strip resulted in surface wrinkles. The second and most satisfactory method of construction has been to prepare a paint in a manner identical with that for the resistive paint with one difference; for the conductive strip, finely divided silver was substituted for the carbon black. A conductive strip of this sort is flexible and rugged, just as is the resistive strip prepared in the same general manner. In sealing these devices, liquid neoprene was spread along the edges and along one end of two rubber strips, and the edges were clamped. The entire unit was heated at 150 F for 1 hour. In order to provide an airtight seal, the unsealed end was

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\* Manufactured by Shawinigan Products Corporation, Shawinigan Falls, Quebec, Canada; Main Offices: Empire State Building, 350 Fifth Avenue, New York 1, N. Y.

\*\* Manufactured by Goodyear Tire and Rubber Company, Akron, Ohio; distributed by W. J. Rusco Company, 2170 West Market Street, Akron, Ohio.

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coated with liquid neoprene, a hypodermic needle was inserted into this end of the device, and the end was clamped. A positive pressure was then applied through the needle, and the needle was carefully withdrawn. The above baking procedure was then followed.

A portion of a transducer made of rubber, with a slight positive air pressure to maintain the spacing between the strips, is sketched in Figure 1.

Several samples of this model of the transducer were constructed and tested. The dimensions were about 1/4 inch in width by 3/32 inch in thickness by 7 inches in length, and the resistance used was about 8,000 ohms per inch. Considerable difficulty was experienced in producing and maintaining a suitable airtight seal. When a suitable seal was obtained, the operation of these devices was satisfactory. When this model of the transducer was checked in a standard  flat-topped output pulses of 1- to 2-milli-second duration were obtained, depending on the particular key operated.

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In view of the difficulty of producing and maintaining a proper seal, alternative methods of construction which would produce the same general configuration were investigated. The first of these alternatives made use of a base material other than rubber - namely, polyvinyl chloride. This clear plastic was selected because of its favorable dielectric properties. These were such that pieces of polyvinyl chloride could be readily welded or fused together by means of a dielectric heater. Transducers with excellent electrical characteristics were prepared using this material and fabrication method. The resistive and conductive strips were constructed by masking and painting with the resistive and conductive mixtures already described. The spacing between elements was maintained by means of a slight positive air pressure

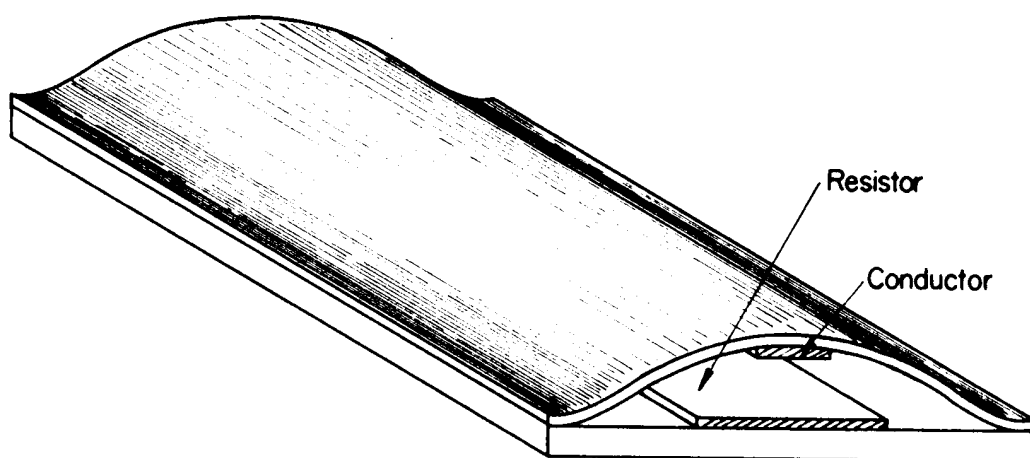
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FIGURE 1. SKETCH OF CROSS SECTION OF TRANSDUCER USING RUBBER AS BASE MATERIAL

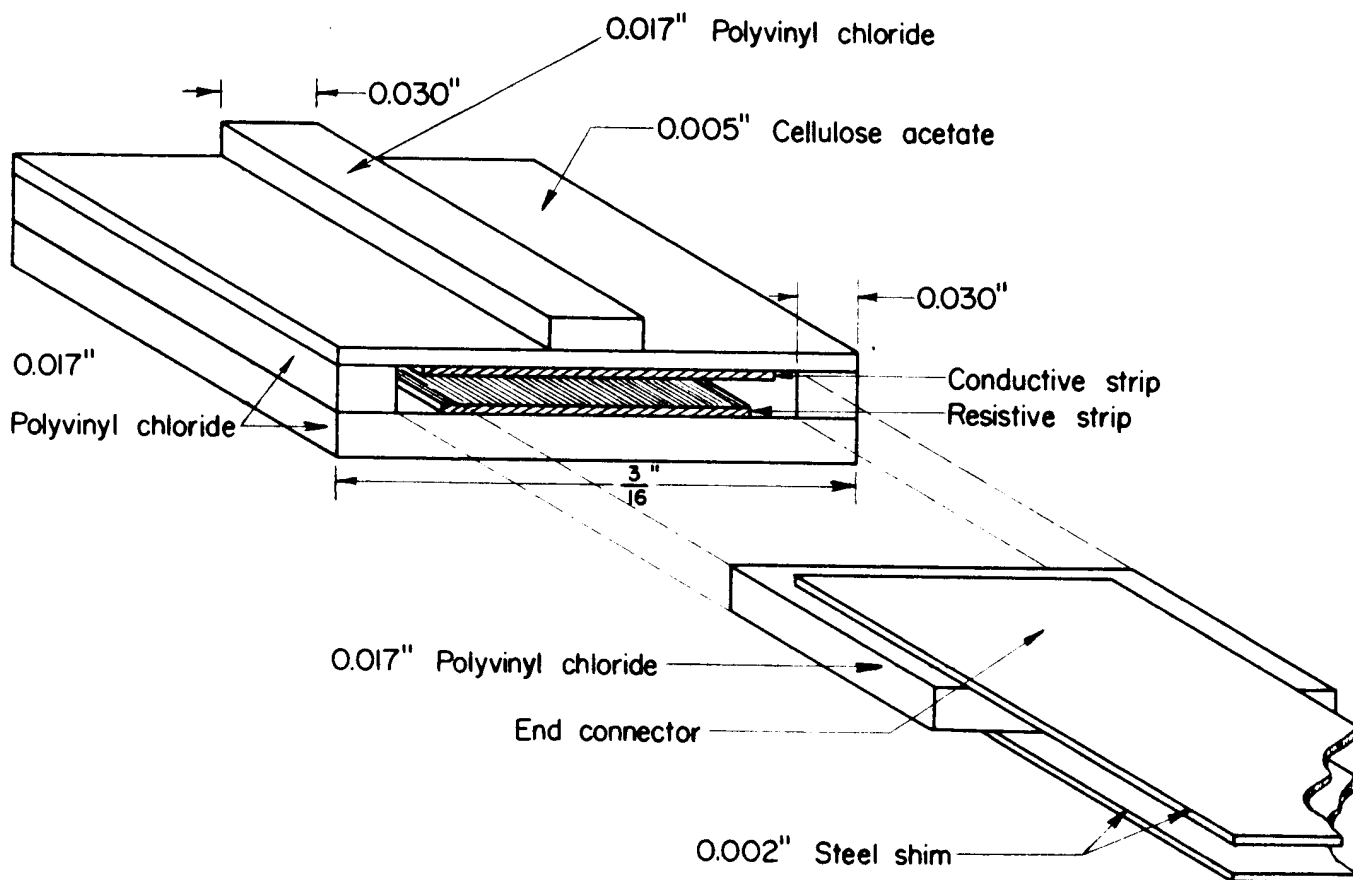


FIGURE 2. SKETCHES OF CROSS SECTION OF TRANSDUCER USING POLYVINYL CHLORIDE AS BASE MATERIAL, AND OF END CONNECTOR

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in the same manner as has already been described. Polyvinyl chloride transducers proved to be more satisfactory than those previously constructed using rubber as the base material; however, considerable care was still required in the preparation of this model of the transducer.

Since the principal difficulty had been concerned with producing an airtight seal that would permit maintaining positive pressure in the transducer, it was deemed worth while to attempt to eliminate this requirement. To this end, a transducer configuration was devised that maintained the spacing between the resistive and conductive strips mechanically. A transducer of this type is illustrated in Figure 2.

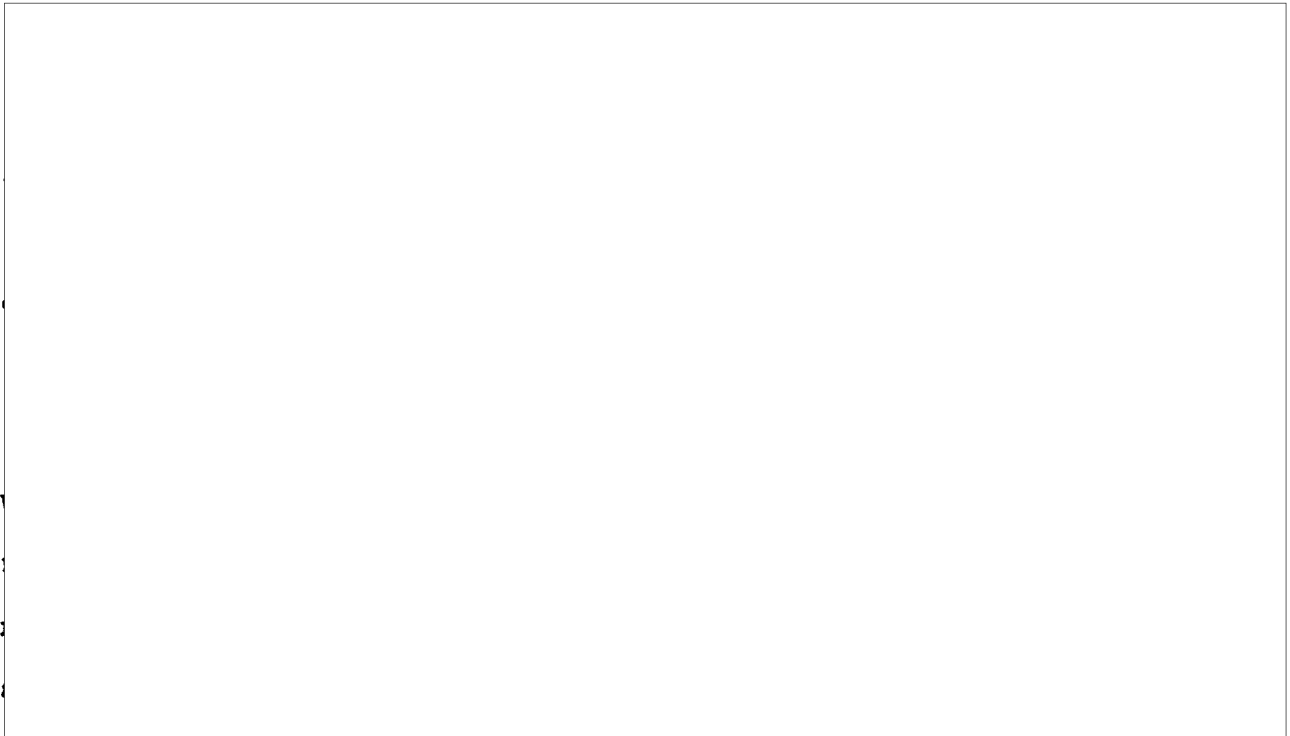
This form of the device was constructed as follows: The previously mentioned resistive coating was applied to a relatively wide strip of polyvinyl chloride. Then, relatively narrow end strips of polyvinyl chloride were glued along the edges of the wide strip. The conductive coating was applied to a strip of 0.005-inch-thick celluloid. This celluloid strip was glued to the narrow end strips in a way that the conductive and resistive elements faced each other. The spacing between these elements was maintained at about 0.017 inch by controlling the dimensions of the narrow end strips. In order to permit the type bars to deflect the celluloid surface so as to make contact with the resistor, a strip of polyvinyl chloride was glued to the outside surface of the celluloid strip for the type bars to strike and rest upon. The glue or bonding material used in preparing this type of transducer was Pliobond 20.

Electrical connections were made to this device in a very simple manner through the use of end connectors. As shown in Figure 2, two sheets of metal foil (in this case, thin steel strip) were glued with Pliobond 20

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to opposite sides of a block of polyvinyl chloride. This assembly was dimensioned in such a way that it just slipped into the open ends of the transducer. Thus, the two pieces of metal foil were in contact with the resistive and conductive strips. In order to maintain this connection, a small ring of steel (e.g., thin-wall stainless steel tubing) cut to proper dimensions was slipped over each end of the transducer and squeezed, thus applying pressure to the contacts and insuring the maintenance of electrical continuity. Duplication of transducers was made relatively easy by this assembly method. The detailed dimensions of the units are given in Figure 2. The electrical performance of this type of unit proved to be very satisfactory. In consideration of the ease of construction and the superior performance of these units, this configuration is believed to be the most satisfactory of those developed.

#### Alternative Transducer Locations



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transducer will depend on the power supply available, but will certainly be far below the safe dissipation limit. Even though the transducers so far produced have been manufactured by hand methods, the linearity is quite reasonable. A resistance vs position curve is shown in Figure 5 for a typical transducer.

#### Transducer Life

Transducers of the most satisfactory type (see Figure 2) have been life tested. The test extended for one million operations corresponding to

[redacted] and then was terminated. The transducer was still in good operating condition when the test was concluded.

This life is equivalent to many months [redacted] and is considered adequate for the proposed application.

25X1

25X1

#### Decoding Apparatus

25X1

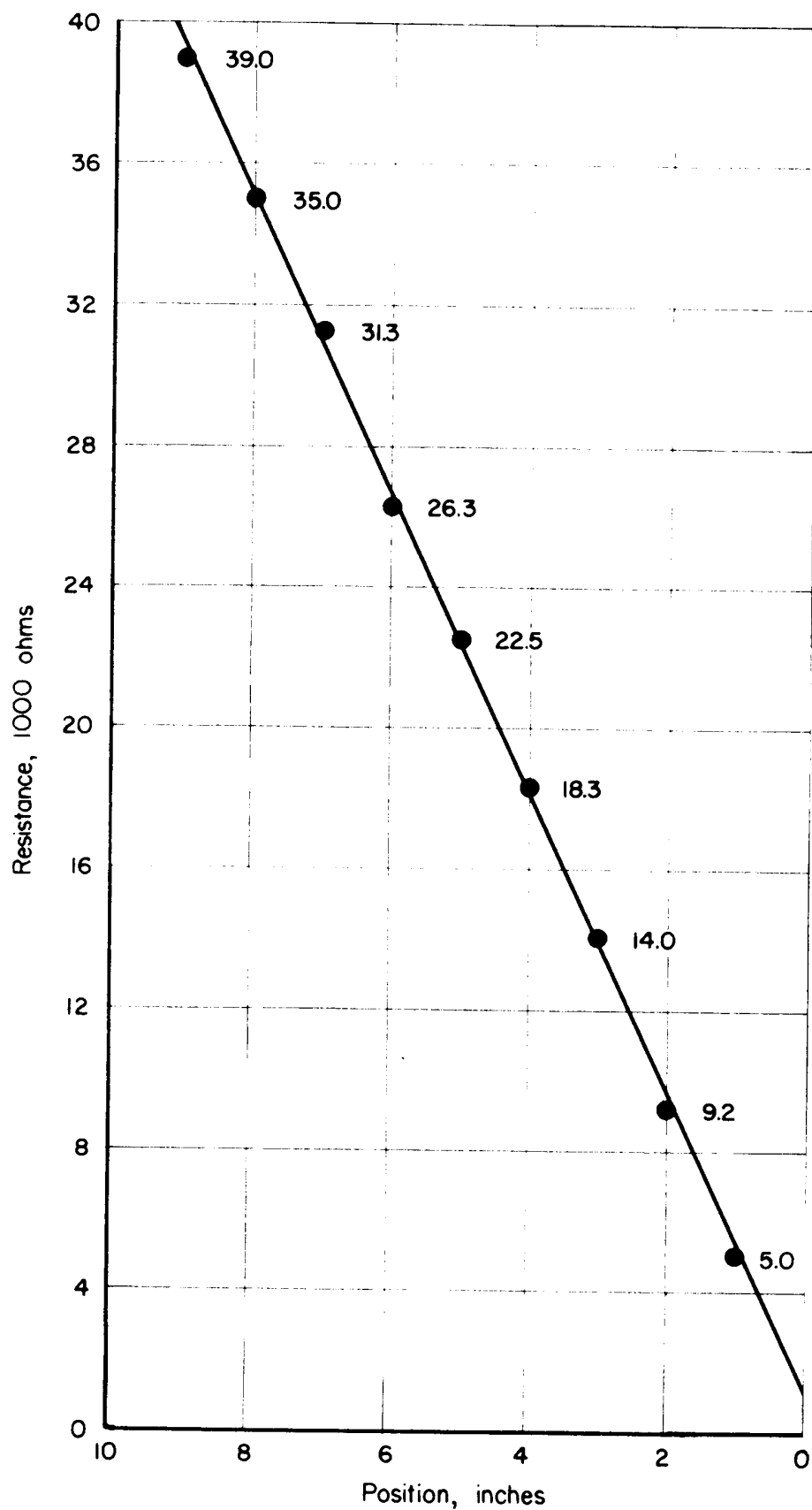


FIGURE 5. PLOT OF RESISTANCE VERSUS POSITION FOR TRANS-DUCER

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A single section of a 12AT7 tube is arranged with a relay in its plate circuit.  $R_2$  and  $R_3$  form a biasing system which controls the bias of the tube so that any desired voltage can be required at the input terminal to cause the tube to conduct and the relay to pickup. Thus, the arrangement is amplitude sensitive. As many of these elements as required can be used to provide relay operations corresponding to various pulse amplitudes. The contacts of the relays are interlocked to provide an output only at the relay that is set for the greatest amplitude as each pulse is received. (Of course, a given amplitude in such a parallel arrangement results in the pick-up of all channels set for an amplitude less than that of the incoming pulse.) In order to provide an input signal of sufficient duration to operate the relays, a pulse-stretching system was used. This device is shown schematically in Figure 7.

The pulses from the transducer are amplified and applied to  $C_1$  through a rectifier. The rectifier is arranged so that  $C_1$  charges quickly, but must discharge through the reverse resistance. Thus,  $C_1$  holds the grid of the tube, and therefore the output of the system, so long as  $C_1$  retains its charge.

In order to utilize this system, the decoder was arranged with an output pulse tuning system. Thus, after the decoder operated, a relay action which takes place at a predetermined time after the beginning of the pulse discharges  $C_1$  through the relay contacts and resets the system for the next impulse. This system was constructed with five channels since the parts required were readily available for that number. Operation of the system was very satisfactory.

25X1

25X1

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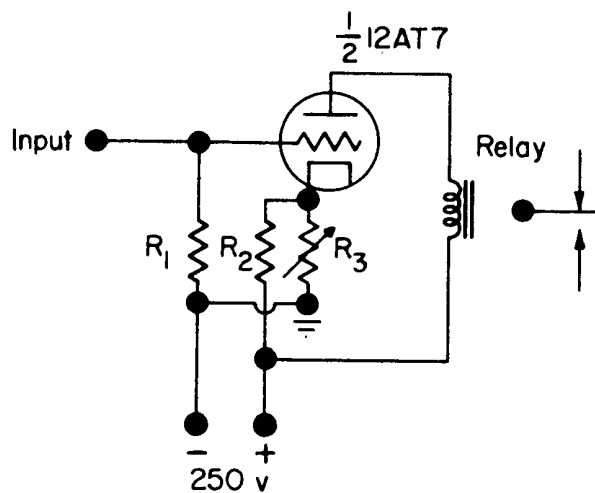


FIGURE 6. DIAGRAM FOR BASIC DECODING CIRCUIT

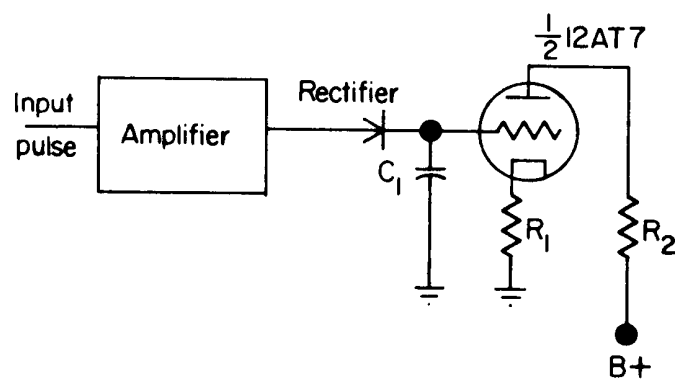


FIGURE 7. SCHEMATIC DIAGRAM FOR DECODER PULSE-STRETCHING SYSTEM

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